RESPONSE OF WETLAND SOILS TO FLOW ALTERATIONS IN THE SABINE RIVER BELOW TOLEDO BEND DAM FOR THE TEXAS INSTREAM FLOWS PROGRAM

A Senior Scholars Thesis

by

DESERI DAWN NALLY

Submitted to the Office of Undergraduate Research
Texas A&M University
in partial fulfillment of the requirements for the designation as

UNDERGRADUATE RESEARCH SCHOLAR

April 2011

Major: Ecological Restoration

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Research Advisor:	Georgianne Moore
Director for Honors and Undergraduate Research:	Sumana Datta

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ABSTRACT

Response of Wetland Soils to Flow Alterations in the Sabine River below Toledo Bend Dam for the Texas Instream Flows Program. (April 2011)

Deseri Dawn Nally
Department of Ecosystem Science and Management
Texas A&M University

Research Advisor: Dr. Georgianne Moore
Department of Ecosystem Science and Management

Hydric soils are a key component to the development of wetland ecosystems. It is well documented that dams change the hydrology and sediment deposition of regulated rivers which can alter hydric soil properties on the riparian wetlands. This research looks at four different techniques to establish if hydric conditions have changed below the Toledo Bend Dam: pH, redoximorphic features (“redox”), presence of Ferrous Iron (Fe $^{+}$2), and the chroma of soil colors. Three riparian wetland sampling sites were identified below the dam using high radar LIDAR digital elevation modeling. Soils were collected from each stratum to a depth of 50 cm using a stratified random approach. Distinct patterns were observed in regards to the pH, redox, Ferrous Iron, and color of soils at the three research sites. In general, soils had a lower pH and more redox potential with decreasing elevation and with increasing distance from Toledo Bend Dam suggesting only the lowest elevations were hydric soils. Reduced conditions detected by ferrous iron also indicated that sites farthest from the dam were retaining hydric properties. Chroma color, although less consistent, also supported the reduced effect on sites downstream.

The results are to be presented to the Texas Instream Flow program to help assess the conditions of the Lower Sabine River.

DEDICATION

I would like to thank my family and parents, Jack and Shelia Nally, for support in this and every endeavor I undertake. For his enduring patience I would like to thank Brent Harris.

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NOMENCLATURE

LIDAR	Light Detection and Range modeling
NRCS	National Resources Conservation Service
Redox	Redoximorphic Features or Mottles

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CHAPTER I

INTRODUCTION

Since the earliest human records, people have depended on river ecosystems. Rivers not only supply food and water, they also supply many other ecosystem services such as water regulation, purification, nutrient cycling, and pollution sinks. For instance, nutrient rich sediment deposited by rivers creates bottomland hardwood forest valuable to the lumber industry. Services such as spiritual and aesthetic are harder to put a value on, but are still deeply ingrained into our culture. Even with all the services offered by these systems, their unpredictable hydrological patterns have led to cost of property and life.

Rivers are subject to flood pulses that keep them healthy by causing disturbances that help with succession processes that promote species diversity and flush out pollutants (William and Haeuber, 1998; Bolze *et al.,* 2010; Johansson and Nilsson, 2002). This frequent saturation of floodplain soils creates anaerobic soil conditions that support vegetation communities such as bottomland hardwood forest. With the introduction of dams to these systems, flood pulses, as well as other hydrological processes have been greatly altered (Friedman *et al*., 1998; Baldwin and Mitchell, 2000; Gregory *et al.*, 1991). Generally, dams reduce the flood frequency and time of inundation or saturation. In cases where it is evaluated that dam removal is beneficial to an ecosystem, the public

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This thesis follows the style of *River Research and Application*.

and local governments may be opposed due to unknown consequences of the removal (Graber and Johnson, 2002). This leads to the need to understand what type of hydrological processes are needed in each system, and how we can repair them with present restraints. With the knowledge of the importance of free-flowing rivers, states have developed new tools based on sound research, to assess the conditions of their rivers with the ultimate goal of regulating instream flow. Instream flows are considered the amount of water that should be present in a river or stream for it to perform its function (Rushton, 2000). Washington and Oregon State were one of the first to initiate an instream flow program (Rushton, 2000; Pilz, 2006). Soon other states formed programs such as the Tennessee Wildlife Resource Agency Instream Flow Program (TWRA, 2010; Foster 2010) and Policy for Maintaining Instream Flows in Northern California Coastal Streams (Water Resources Control Board, 2010) to assess their own rivers. There are currently organizations such as the Instream Flow Council (Annear *et al*., 2009), that are attempting to help and encourage states to create national and international assessment tools and standards for monitoring instream flows and river health. Creating these assessment tools requires in-depth knowledge of past and present conditions of rivers. This newest knowledge of assessing instream flows is currently being used by Texas agencies to evaluate stream conditions. In 2001 the 77th Texas legislature Senate Bill 2 created the Texas Instream Flow Program (Mallard *et al.*, 2005). The focus of the Texas program is to apply in-depth and research based techniques to the field of instream assessment. Senate bill 2 focuses on three Texas Rivers: Sabine, Brazos, and San Antonio.

The Sabine River's largest dam is the Toledo Bend Dam. Built in 1967, it is unknown how much this dam has affected the ecosystem services provided by Sabine River wetlands. Immediately downstream of the dam, the channel has become sediment starved, although the sediment regime appears to return to historic levels by several kilometers downstream (Phillips, 2003). Sediment deposits are evident downstream, but potential changes in the hydrology and resulting changes in the wetland status have not been thoroughly evaluated. Frequency, timing, and duration of flooding are all factors that develop hydric soils. Since hydric soils require being inundated with water until they form an anoxic state, they are useful indicators of wetland health. Hydric soils and vegetation associated with them are essential for ecosystem services (Mooney *et al.,* 2005). When these natural flows are interrupted, it can change the natural cycles and cause drying and oxidation (Baldwin and Mitchell, 2000). This makes evaluation of hydric soils a possible tool to help Texas Instream Flow program determine the health of the Sabine River.

For instance, soil redox can be observed to determine the state of oxidized and anoxic conditions. Likewise, soil pH might indicate changes in wet and dry cycles in the soil. Though it has not been used much, it is known that acidic hydric soils tend towards circumneutral during saturation periods (Wharton *et al.*, 1982; Cook *et al.*, 2009; Gosselink and Mitsch, 1986). It is possible that pH may vary across gradients of soil saturation that develop in floodplains subject to more flooding in low-lying areas and less flooding at higher elevations. It follows that soil pH may provide evidence of changing flooding conditions (e.g. soils that were frequently saturated in the past and less saturation at the current time). Since this property of soil is an uncommon wetland indicator, it must first be determined if pH can serve as an adequate test for determining the condition of hydric soils. Observing colors of hydric soils is another simple way to discover its anoxic state (Hurt *et al*., 2003). Hydric soils have a Munsell chroma color of ≤ 2 with redox and ≤ 1 without redox, while soils that are aerobic have a lighter color (Environmental Laboratory, 1987). Soil pH, redox, ferrous iron test, and chroma colors together are powerful tools to detect current and changing soil properties. Titus (1990) and Collins *et al* (1982) found that minor elevation changes can have major impacts on vegetation such as seedling growth and safe sights for invasive species. If altered hydrology has changed sediment delivery, and the length of time soils are saturated, then it would be expected for zones of the wetlands to transition from hydric to non-wetland soils, especially in locations that are topographically high. Focusing on soils in sloughs (lowlands), levees (uplands), and midlands helps interpret how soils vary along elevation gradients. The objective of this study was to evaluate if the Sabine River is retaining its hydric soils south of Toledo Bend Dam. If the hydrology has changed after the dam was constructed, we expect hydric to non-hydric soil transitions will be evident in specific zones adjacent to the river (e.g. higher elevation sites) and in sites located upstream closer to Toledo Bend dam. Since soil pH has not been fully established as a wetland indicator, the second objective of this study is to look at soil pH along with the combined measurements of soil redox to develop a robust indicator of hydric soils on the Sabine

River floodplain. The analysis of the Sabine River's hydric soils will be reported to the Instream Flow Program in order to help determine the health of the Sabine River wetlands downstream of Toledo Bend Dam.

CHAPTER II

METHODS

Study site

The Sabine River, that forms most of the Texas-Louisiana boarder, is over 483 km long with a total drainage basin of approximately 25,270 km^2. The subtropical climate produces an annual precipitation of 1100 mm to 1200 mm that falls throughout the year. During mid-summer, drought can occur followed by tropical storms that can cause flooding of lowlands for days to weeks (Cushing, 2005). Common vegetation found in this bottomland hardwood forest is Sweetgum (*Liquidambar styraciflua*), Water Tupelo (*Nyssa aquatica*), Bald cypress (*Taxodium distichum*), poison ivy (*Toxicodendron radicans*), green briar (*Smilax bona-nox*), and Graybark Grape (*Vitis cinerea*). In 1969 the Toledo Bend Dam was completed and separated the river into upper and lower sections. In order to determine the effect of the dam, this research focuses on the lower Sabine River.

Three sites were chosen: Anococo Bayou, Big Cow Creek, and Sabine Island. Details of how these sites were selected are provided in the section below. According to the NRCS Soil Survey classification (Soil Survey Staff, 2011) the Sabine Island site has a 70% dominance of Guyton and Bienville soils with a pH that averages 4.8 while 22% of the site has Barbery mucky clay that averages a 7.5 pH. The Big Cow Creek site is 53% Urbo and Matachie soils of pH 5.0, 9% Bernaldo-Besner soil of pH 5.6, and a small percentage of other soils that occured in our sampling area. The Anacoco Bayou site had the least soil-type diversity with the entire site being classified as Urbo-Matachie soils.

Sample collection

Three qualified sites for this research were selected within 500 m of the river based on topography, time since logging of at least 60 years, and accessibility. The site closest to the Toledo Bend dam is Anacoco Bayou located 79 km downstream (N30^0 48’ 14.3” W93^{0}34’08.6”). Big Cow Creek site is located downriver of the Anacoco Bayou site, 103 km from the dam (N30^{0}40’11.9” W93^{0}39’26.7”), while Sabine Island is farthest from the dam, 204 km downstream (N30^{0}10’50.9” W93^{0}42’33.8). Each site was separated into nine plots based on topography, with three plots each in lowlands, uplands, and midlands, respectively. Five potential sampling plots were selected using a digital elevation model from Louisiana atlas statewide GIS converted to ESRI ArcMap. Of the five sample sites, three were sampled while two sites remained available as alternates.

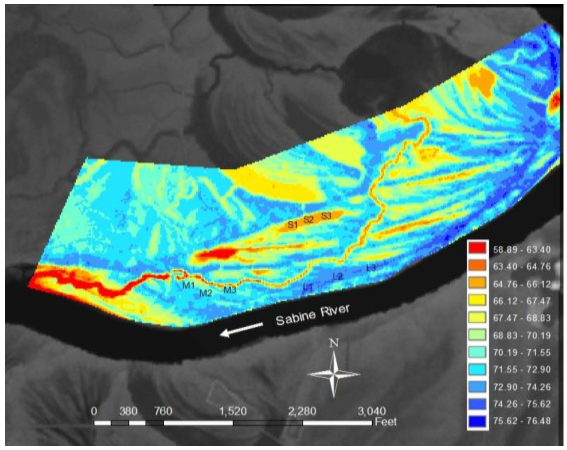

Figure 1. Anacoco Bayou elevation map of Lowlands (S1,S2,S3), Midlands(M1,M2,M3), and Uplands (L1,L2,L3). Elevation units are in feet above sea level

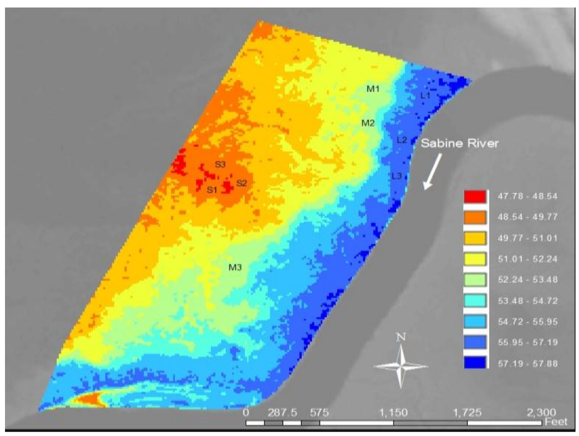

Figure 2. Big Cow Creek elevation map of Lowlands (S1,S2,S3), Midlands (M1,M2,M3), and Uplands (L1,L2,L3). Elevation units are in feet above sea level

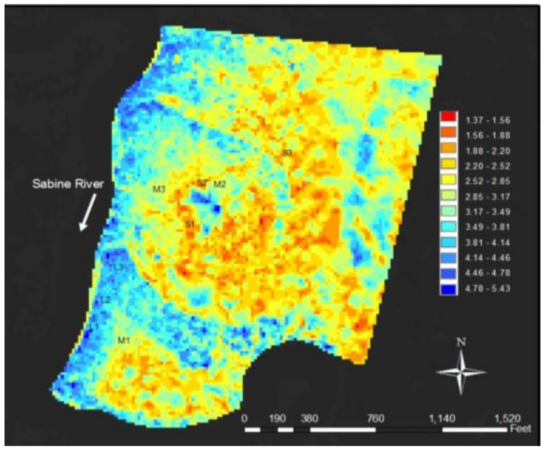

Figure 3. Sabine Island elevation map of Lowlands (S1,S2,S3), Midlands (M1,M2,M3), and Uplands (L1,L2,L3). Elevation units are in feet above sea level

Upon locating the plot GPS coordinates, the stratified random sampling method was used to locate and mark 10 m × 10 m plots. For each plot, four points were selected for sampling (Figures 1, 2, and 3). The first point was determined by random selection, while points 1-m North, South, and East of the central location were measured. I extracted 100−300 g soil samples from each stratum to a depth of 50 cm.

Soil analysis

For pH testing, samples were air dried, sifted with a 2 mm sieve, and major roots and debris removed. From this process 10 g of soil and 25 mL of deionized water was added. The suspension was then stirred for one minute and allowed to rest for one hour (Carter, 1993). A model Ecosense pH10 (YSI, inc., Yellow Springs, Ohio) was placed into the supernatant that was gently stirred prior to measurement and allowed to settle briefly before pH was recorded.

I observed redoximorphic features two ways: ferrous iron test and presence of mottles. One droplet of alpha-alpha-Dipyridyl solution was applied in the field to each identified stratum of freshly excavated soil to test for ferrous iron (Fe^{2+}). Soils that test positive for ferrous iron indicated they were currently in a reduced hydric state associated with wetland conditions. A negative test indicated that oxidation is occurring and anaerobic conditions of hydric soils are not present at the time (Environmental Laboratory, 1987) associated with temporary or seasonal drying of soil. Soil mottles were also observed to determine if reducing and oxidation cycles were occurring in the system. The appearance of reddish and dark colored patches along oxidized root channels were indicative of mottles formed when the soil is saturated long enough for ferrous iron to move through the system and then become oxidized during the dry season when oxygen can move through the soil. The oxidization of ferrous iron looks orange or red in the soil matrix and indicates hydric properties.

Each sample was examined in the lab for hydric color properties by using Munsell coloring of the matrix in moist to air-dried conditions. For soils to be classified as hydric soils they must have a Munsell chroma color of ≤ 2 with mottles or a chroma of ≤ 1 with no mottles (Environmental Laboratory, 1987).

We analyzed the results of pH by site and elevation by comparing mean differences using analysis of variance followed by post-hoc Fisher's LSD multiple comparisons procedure (JMP v8, SAS, Inc., Cary, NC).

CHAPTER III

RESULTS

Elevation effects on pH

Distinct soil pH patterns were observed in the research sites. Soil pH averaged 4.93 ± 0.04 in the lowlands, 5.30 ± 0.05 in the midlands, and increased to an average of 5.75 ± 0.05 in the uplands (figure 4). Patterns of pH were normally distributed (Figure 5).

Average pH of Elevation

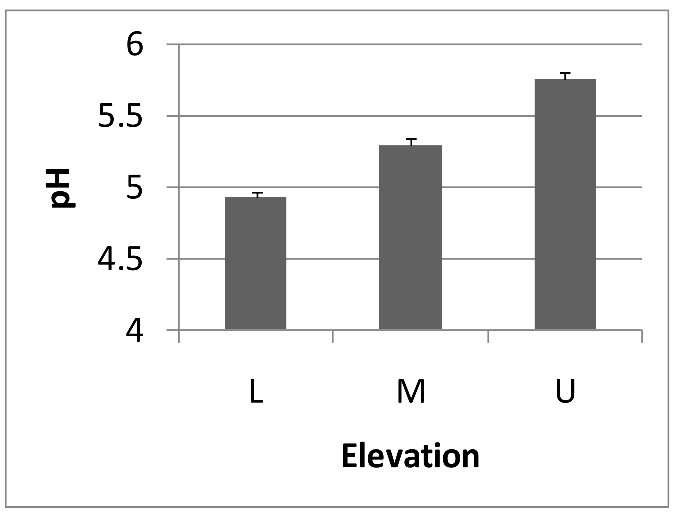

Figure 4. Average pH recorded at elevation of Lowland (L), Midland (M), and Upland (U) of each plot using a total of 272 soil samples

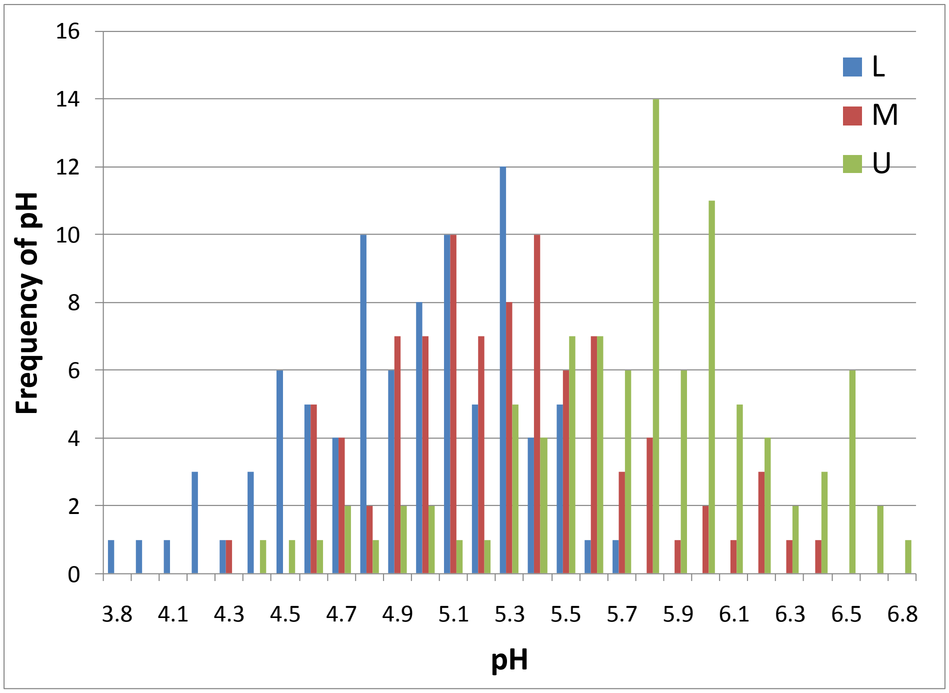

Figure 5. Frequency of pH and pH recorded at the Lowland (L), Midland (M), and Upland (U) of each plot using 272 soil samples

A similar pattern was observed in the elevations of each site. The Anacoco Bayou had the greatest elevation difference of 2.8m between the lowland and upland plot. The soil pH of this plot also had the greatest difference of 1.3 units from the lowland reading of 4.7 to the upland at 6.0. Big Cow Creek sites had a slightly smaller evaluation change of 2.6m, and a pH difference of 0.8. At the Sabine Island site there was only a 0.6m elevation variance and lower elevation of all the sites, but the same pattern of lower pH increasing to higher pH with a 0.3 difference was observed (Figure 6).

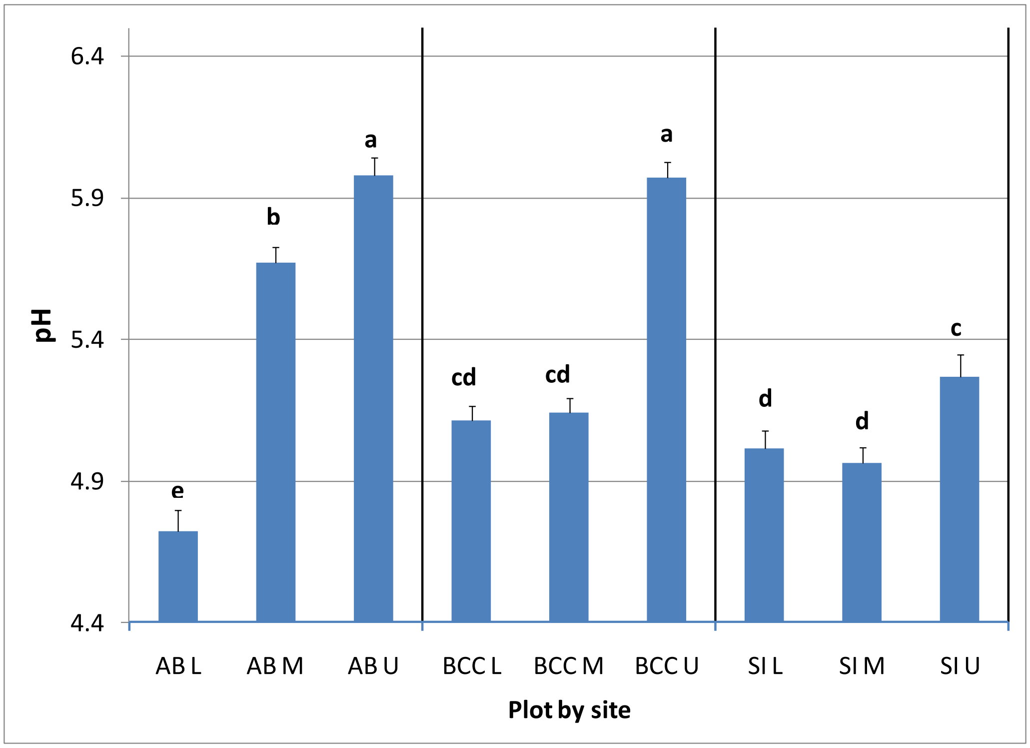

Figure 6 Average pH of Anacoco Bayou (AB), Big Cow Creek (BBC), and Sabine Island (SI) sites and plot elevation of Lowland (L), Midland (M), and Upland (U). Means with different letters are significantly different (Fisher's LSD test).

Redox and pH

Redox (mottles) was observed by site and elevation to determine any trends that would correlate to the hydric conditions of the sites (Figure 7). Each site had a large percentage of mottles present. Anacoco Bayou had 56% of the samples taken present redox. Big Cow Creek had 71% and Sabine Island 74% of observed soil samples with redox. This could be due to Sabine Island retaining acidic hydric soils that reduce the saturation time required for redox features to develop (Brookins, 1988). Mottles were more frequent in the lower elevations and less frequent in the upper elevations at Anacoco Bayou and Big

Cow Creek. However, at Sabine Island, this trend reversed. Sabine Island had more mottles at midland and upland elevations. This may be associated with continuous anaerobic saturated conditions in the lowest elevations at that site.

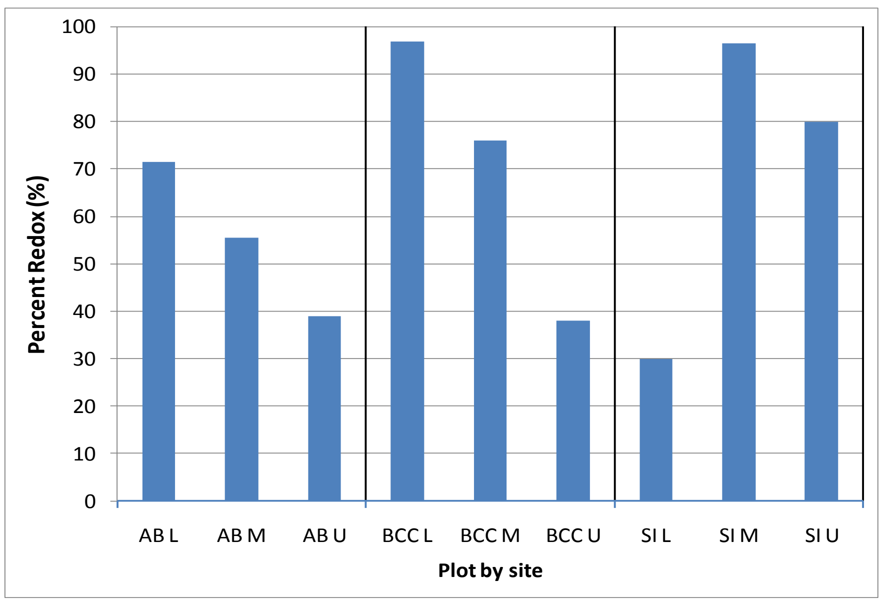

Figure 7. Percentage of redox features (mottles) found in the Lowlands (L), Midlands (M), and Uplands (U) at Sabine Island (SI), Anacoco Bayou (AB), and Big Cow Creek

Ferrous iron test

The ferrous iron test using alpha-alpha Dipyridyl showed that few soil samples where in a reduced state. A large number of soil samples from Sabine Island tested positive compared to the Anacoco Bayou site, while no samples showed reduced conditions at the Big Cow Creek site (Table 1).

Table 1 Samples that tested positive for ferrous iron that indicate hydric soils compared to total samples taken at Anacoco Bayou (n = 106), Big Cow Creek (n = 84) and Sabine Island (n = 79).

	Anacoco Bayou	Big Cow Creek	Sabine Island
Positive for Ferrous Iron	6	0	26
Negative for Ferrous Iron	100	84	53
Total Test	106	84	79
Percent Positive	6%	0	21%

Chroma indicators of hydric soils

A distinct pattern in wetland colors (i.e. chromas of 2 and lower) was seen as the sites moved farther away from Toledo Bend Dam. In the high elevation sites, Anacoco Bayou and Big Cow Creek, the uplands had an equivocal percentage of hydric and non-hydric coloring. Anacoco Bayou had 58% of the soil samples indicating hydric colors while Big Cow Creek had 56%. This is expected due to the higher elevation. The Sabine site had 91% of its soil samples indicate hydric colors (Table 2). This is expected since the lower elevations should have more water saturation that causes the distinct chroma colors of hydric soils.

Table 2. Samples with Positive Munsell chroma colors that indicate hydric soils compared to total samples taken at Anacoco Bayou (n = 106), Big Cow Creek (n = 84), and Sabine Island (n = 79)

	Anacoco Bayou	Big Cow Creek	Sabine Island
Chroma ≤ 2 with mottles	**51**	**43**	**58**
Chroma ≤ 1 w/o mottles	**10**	**4**	**14**
Total Positive Chroma	**61**	**47**	**72**
Percent of Hydric Chroma	**58%**	**56%**	**91%**

CHAPTER IV

SUMMARY AND CONCLUSION

The properties of soils recorded during this research strongly suggest that hydric properties are not being maintained at sites closest to the dam. At distances farther from the dam, results indicate that hydric properties increase and little influence of the dam was observed. The pH at Anacoco Bayou was not as consistent as it was at Sabine Island and Big Cow Creek sites. The expected pH of this Urbo soil should be around 5.0. Most plots showed the expected pH, but in the lowland plots a lower pH of 3.8 and 3.9 was observed. Since this site shows some lower than expected pH, this could indicate that flooding is no longer having an effect on the system. Processes such as rain leaching can often influence soil by reducing its pH (Helyar *et al.*, 1999). Anacoco Bayou also had a low percentage of mottles and only 6% of samples tested positive for ferrous iron. All together, these results suggest this site is not being saturated for adequate periods of time (He, 2003).

Hydric properties of the Big Cow Creek site indicated that this location is in transition to more non-hydric properties. The pH and mottles observed at this site suggests that this site experiences periods of saturation, but not as long as observed at the Sabine Island site. The fact that this site had no samples test positive for ferrous iron and had the lowest percent of hydric chroma colors both provided evidence that it is not currently receiving long saturation periods. As with the Anacoco Bayou site, pH of soils and redox responded sharply to changes in elevation. The upland plots were in Bernardo-Besner soils with pH of 5.6 while the lowland and midland plots were located in Urbo and Matachie soils of pH 5.0.

Sabine Island soils more commonly exhibited hydric properties, no matter the elevation, compared to the other two sites. Soil pH was generally low and only increased slightly in the upland elevations. If acidic soils are saturated for long enough periods of time, I would expect to see increases in pH toward circumneutral and regular movement of ferrous iron through the system. Instead, the consistently low pH and high percentage of mottles demonstrates that this site is not only currently saturated, but it also receives regular wet/dry cycles. In addition, chroma colors and ferrous iron tests support the other indicators of saturated soils. All of the soils sampled at Sabine Island were classified as Guyton and Bienville which typically have a pH of 4.8 compared with my observed average of 5.1.

Due to the dynamic nature of this ecosystem, it is necessary to observe many properties to assess the overall condition of an area to determine whether it meets wetland qualifications. Munsell colors are best identified when soil samples are being collected and still field moist. While color results were fairly consistent with the other types of tests and with expected soil series classifications, one third of the soil samples were identified in the field while the rest were stored for up to a month before testing.

The objective of establishing pH as a good field indicator is still uncertain. One obstacle to overcome is the correct identification of the soil being tested. The NRCS soil survey can give a general classification of soils in the area, but it is not designed to catch small areas of soil variability that could greatly influence pH results and interpretation. In conclusion, the use of four combined soil test provided more detailed and comprehensive information while pH could be used as a first indicator that the system needs further evaluation.

REFERENCES

Annear T, Lobb D, Coomer C, Woythal M, Hendry C, Estes C, Williams K. 2009. *International instream flow program initiative, A status report of state and provincial Fish and Wildlife Agency instream flow activities and strategies for the future,* Final report for multi-state conservation grant project. Instream Flow Council: Cheyenne, WY.

Baldwin DS, Mitchell AM. 2000. The effects of drying and re-flooding on the sediment and soil nutrient dynamics of lowland river–floodplain systems: A synthesis. *Regulated Rivers: Research & Management* **16**: 457–467.

Bolze S, Meissner K, Rinklebe J, Rupp H. 2010. A scale-dependent approach to study pollution control processes in wetland soils using three different techniques. *Ecological Engineering* **36**: 1439 -1447

Brookins DG. 1988. *Eh-pH diagrams for geochemistry.* Springer-Verlag, Heidelberg, Berlin

Carter MR. 1993. *Soil sampling and methods of analysis*. CRC Press LLC: Boca Raton, FL.

Collins SL, Perino JV, Vankat JL. 1982. Woody vegetation and microtopography in the bog meadow association of Cedar Bog, a west-central Ohio fen. *The American Midland Naturalist* **108**:245-249.

Cook HF, Bonnett SAF, Pons LJ. 2009. *Wetland and floodplain soils: Their characteristics, management and future, in The Wetlands Handbook.* Wiley-Blackwell: Oxford, UK.

Cushing CE. 2005. *Rivers of North America.* Elservier Acedemic Press: Burlington, MA.

Environmental Laboratory. 1987. *Corps of Engineers Wetlands delineation manual. Technical Report Y-87-1*, U.S. Army Engineer Waterways Experiment Station: Vicksburg, MS.

Friedman JM, Osterkamp WR, Scott ML, and Auble GT. 1998. Downstream effects of dams on channel geometry and bottomland vegetation: regional patterns in the Great Plains. *Wetlands* **18**: 619-633.

Foster R. 2010 *Instream flow issues: Declaration of policy and purpose.* Tennessee Department Environmental Control.

Gosselink, J., Mitsch, W. 1986. *Wetlands*. Van Nostrand Reinhold Company: NewYork, NY.

Graber BE, Johnson SE. 2002. Enlisting the social sciences in decisions about dam removal and river restoration. *Bioscience* **52**, 731-738

Gregory SV, Swanson FJ, Mckee WA, Cummins KW. 1991. An ecosystem perspective of riparian zones. *Bioscience* **41**: 540-551

He, X. 2003. A method to predict soil saturation frequency and duration from soil color. Soil Science Society of America. J. **67**:961–969.

Helyar KR, Cregan PD, Godyn DL.1999. Soil acidity in New South Wales current pH values and estimates of acidification rates. *Australian Journal of Soil Research* **28**, 523–537.

Hurt GW, Whited PM, Pringle RF (Eds.). 2003. *Field indicators of hydric soils in the United States, Version 5.01*. USDA, NRCS, In Cooperation with the National Technical Committee for Hydric Soils: Fort Worth, TX.

Johansson M, Nilsson C. 2002. Responses of riparian plants to flooding in free-flowing and regulated boreal rivers: an experimental study. *Journal of Applied Ecology* **39**: 971–986.

Mallard GM, Dickson KL, Hardy TB, Hubbs C, Maidment DR, et al. 2005**.** *Science of instream flows: A review of the Texas Instream Flow Program.* National Academies Press: Washington D.C.

Mooney HA, Reid WV, Cropper A, Capistrano D, Carpenter SR, et al. 2005. *Millennium ecosystem assessment ecosystems and human well-being: Synthesis.* Island Press: Washington, DC.

Pilz RD. 2006. The confluence: Oregon's instream water rights law in theory and practice. *Environmental Law* **36**:1383

Phillips JD. 2003. Toledo Bend reservoir and geomorphic response in the lower Sabine River. *River Research and Application* **19**:137-159

Rushton CD. 2000. *Instream flows in Washington State of Washington past, present and future*. Water Resources Program, Department of Ecology: Olympia, WA.

Soil Survey Staff. 2011 Web soil survey of Jasper/Newton County, TX. Natural Resource Conservation Service, United States Department of Agriculture. Web Soil, http://websoilsurvey.nrcs.usda.gov/app/. [Accessed 3/25/2011].

Titus JH. 1990. Microtopography and woody plant regeneration in a hardwood floodplain swamp in Florida. *Bulletin of the Torrey Botanical Club.* ***117****:429-437.*

TWRA Instream Flow Program. 2010. Tennessee Wildlife Resource Agency, <htpp://www.state.tn.us/twra/instream.html>. [September 18, 2010].

Water Resources Control Board. 2010. *Policy for maintaining instream flows in northern California coastal streams:* Sacramento, CA.

Wharton CH, Kitchen WM, Pendelton EC, Sipe TW. 1982. *The ecology of bottomland hardwood swamps of the Southeast: a community profile.* U.S. Fish and Wildlife Services, Biological Services Program: Washington, D.C.

William KM, Haeuber RA. 1998. Flooding: Natural and managed disturbances. *Bioscience* **48**: 677-680.

APPENDIX

Site	UML	Depth	Redox	Redox (+)	Matrix	Color	Chroma	pH	Fe+
BCC	U	2		0	10	6	3	6.1	N
BCC	U	4		0	10	5	1	5.7	N
BCC	U	20	7.5 6/8	1	10	6	4	6.3	N
BCC	U	7		0	10	7	4	5.6	N
BCC	U	12		0	10	5	4	6.2	N
BCC	U	20	5 4/6	1	10	6	4	6.5	N
BCC	U	2		0	10	8	3	5.8	N
BCC	U	12		0	10	5	4	5.8	N
BCC	U	20	7.5 6/8	1	10	6	1	6.4	N
BCC	U	1	7.5 6/8	1	10	8	3	6.3	N
BCC	U	3		0	10	5	1	6	N
BCC	U	12		0	10	5	4	6.5	N
BCC	U	20		0	10	6	1	6.5	N
BCC	U	3		0	10	6	2	5.8	N
BCC	U	20	5 5/8	1	10	6	4	6.1	N
BCC	U	2		0	10	5	2	6.1	N
BCC	U	20	5 5/8	1	10	6	3	5.7	N
BCC	U	2		0	10	4	2	6	N
BCC	U	20	5 5/8	1	10	5	4	5.3	N
BCC	U	2		0	10	4	2	5.5	N
BCC	U	20	5 5/8	1	10	6	3	5.9	N
BCC	U	2		0	10	5	2	5.8	N
BCC	U	20		0	10	6	4	6	N
BCC	U	2		0	10	5	2	5.7	N
BCC	U	20	7.5 6/8	1	10	6	3	6	N
BCC	U	3		0	10	7	3	5.8	N
BCC	U	20	7.5 5/8	1	10	6	3	5.8	N
BCC	U	2		0	10	5	2	5.9	N
BCC	U	20	7.5 6/8	1	10	6	3	6.1	N
BCC	M	2	7.5 6/6	1	10	6	2	4.9	N
BCC	M	20	5 5/8	1	10	5	3	5.3	N
BCC	M	2		0	10	5	2	5.4	N

BCC	M	20	7.5 6/8	1	10	6	2	5.1	N
BCC	M	2		0	10	5	2	5.1	N
BCC	M	20	5 5/8	1	10	5	2	5.4	N
BCC	M	2	5 6/6	1	10	6	3	5	N
BCC	M	20	5 5/8	1	10	5	3	5.7	N
BCC	M	1		0	10	5	2	5.1	N
BCC	M	20	5 5/8	1	10	6	3	5.2	N
BCC	M	1		0	10	5	2	5.1	N
BCC	M	20	5 5/8	1	10	6	4	5.2	N
BCC	M	1		0	10	5	2	4.6	N
BCC	M	20	5 5/8	1	10	6	2	5.2	N
BCC	M	1		0	10	6	2	4.7	N
BCC	M	20	5 5/8	1	10	5	4	5.1	N
BCC	L	3	5 4/6	1	10	4	2	4.8	N
BCC	L	20	10 5/8	1	10	7	2	5.5	N
BCC	L	4	10 7/6	1	10	4	1	5	N
BCC	L	20	7.5 6/8	1	10	7	1	5.5	N
BCC	L	8	7.5 4/6	1	10	4	2	5	N
BCC	L	20	7.5 6/8	1	10	7	2	5.5	N
BCC	L	6	7.5 4/6	1	10	5	1	5.1	N
BCC	L	20	7.5 6/6	1	10	6	2	5.7	N
BCC	M	2	7.5 6/8	1	10	4	2	5	N
BCC	M	20	5 5/8	1	10	6	2	5.3	N
BCC	M	3	5 6/8	1	10	4	2	5	N
BCC	M	20	5 5/8	1	10	5	2	5.4	N
BCC	M	5	5 5/6	1	10	4	2	4.9	N
BCC	M	20	5 5/6	1	10	5	2	5.1	N
BCC	M	3	5 6/8	1	10	4	2	4.8	N
BCC	M	10	5 5/6	1	10	5	2	5.7	N
BCC	M	20	5 5/6	1	10	5	2	5.2	N
BCC	L	6	5 5/6	1	10	5	2	5.1	N
BCC	L	12	7.5 5/8	1	10	5	2	5.3	N
BCC	L	20	5 5/8	1	10	5	2	5.5	N
BCC	L	2	5 6/8	1	10	4	2	4.9	N
BCC	L	11	5 5/8	1	10	4	2	5	N
BCC	L	20	5 4/6	1	10	4	2	5.2	N
BCC	L	3	5 5/8	1	10	4	2	5.1	N
BCC	L	11	5 6/8	1	10	5	2	5.3	N
BCC	L	20	5 6/8	1	10	5	2	5.5	N

BCC	L	3	7.5 6/8	1	10	4	2	4.7	N
BCC	L	12	5 5/8	1	10	4	2	5.1	N
BCC	L	20	5 4/6	1	10	4	2	5.1	N
BCC	L	3	7.5 6/8	1	10	4	2	4.6	N
BCC	L	12	5 4/6	1	10	4	2	5.2	N
BCC	L	20	5 6/8	1	10	5	2	5.3	N
BCC	L	3	7.5 6/8	1	10	4	2	4.5	N
BCC	L	12	5 5/8	1	10	4	2	4.9	N
BCC	L	20	5 6/8	1	10	5	2	5.3	N
BCC	L	12	7.5 4/6	1	10	4	1	4.8	N
BCC	L	3	7.5 4/6	1	10	4	1	4.8	N
BCC	L	20	7.5 5/8	1	2.5	5	2	5.1	N
BCC	L	3		0	10	3	1	4.8	N
BCC	L	15	7.5 5/8	1	10	5	1	5.3	N
SI	U	2		0	10	5	2	5.5	N
SI	U	8	7.5 5/8	1	10	5	2	5.8	N
SI	U	20	7.5 5/8	1	2.5	5	2	4.4	N
SI	U	2	7.5 5/8	1	10	5	1	5	N
SI	U	8	7.5 5/8	1	10	5	2	5.8	N
SI	U	20	7.5 5/8	1	2.5	5	2	4.6	N
SI	U	2		0	10	4	1	5.5	N
SI	U	8	7.5 5/8	1	10	5	2	5.7	N
SI	U	20	7.5 5/8	1	2.5	5	2	4.7	N
SI	U	2		0	10	5	2	5.8	N
SI	U	8		0	10	5	2	6	N
SI	U	20		0	2.5	5	2	4.7	N
SI	U	1	7.5 5/8	1	10	7	2	5.4	N
SI	U	8	7.5 5/8	1	10	7	2	5.3	N
SI	U	20	7.5 5/8	1	2.5	5	2	4.9	N
SI	U	2		0	10	5	2	5.1	N
SI	U	8	7.5 5/8	1	10	7	2	5.6	N
SI	U	20	7.5 5/8	1	2.5	5	2	5.4	N
SI	U	6	7.5 5/8	1	10	7	2	5.5	N
SI	U	20	7.5 5/8	1	2.5	5	2	5.5	N
SI	U	2	7.5 6/8	1	7.5	6	2	5.3	N
SI	U	20	5 5/8	1	10	5	2	5.2	N
SI	M	6	5 4/6	1	10	4	2	5.2	N
SI	M	20	7.5 5/6	1	2.5	5	2	5.1	N
SI	M	6	7.5 5/8	1	10	4	2	4.9	N

SI	M	20	5 4/6	1	10	4	2	4.6	N
SI	M	6	7.5 5/8	1	10	4	2	5.3	N
SI	M	20	7.5 5/6	1	2.5	5	2	5	N
SI	M	6	7.5 5/8	1	10	4	2	5.4	N
SI	M	20	7.5 5/6	1	2.5	5	2	4.6	N
SI	U	5	10 6/8	1	10	6	2	5.6	N
SI	U	20	7.5 5/6	1	2.5	5	2	5	N
SI	U	6	10 6/8	1	10	6	2	5.5	N
SI	U	20	7.5 5/6	1	2.5	5	2	4.8	N
SI	U	6	10 6/8	1	10	6	2	5.6	N
SI	U	20	7.5 5/6	1	10	5	2	4.9	N
SI	U	6	10 6/2	1	10	6	2	5.4	N
SI	U	20	7.5 5/6	1	2.5	5	2	4.5	N
SI	L	9	7.5 6/2	1	2.5	5	2	5.2	N
SI	L	8	7.5 5/6	1	2.5	5	2	5.3	N
SI	L	10	7.5 5/6	1	2.5	5	2	5	N
SI	L	8	7.5 5/6	1	2.5	5	2	5.2	N
SI	M	6	7.5 5/8	1	10	5	2	5.6	N
SI	M	9	5 5/6	1	10	5	2	5	N
SI	M	20	7.5 6/8	1	10	5	2	4.9	N
SI	M	6	7.5 6/6	1	10	5	2	5.1	N
SI	M	20	7.5 5/8	1	2.5	5	2	4.7	N
SI	M	6	7.5 5/8	1	10	5	2	5.4	N
SI	M	20	5 5/8	1	2.5	5	2	5.1	N
SI	M	6	7.5 5/8	1	10	5	2	5.3	N
SI	M	20	5 5/8	1	10	5	2	4.8	N
SI	L	6		0	10	5	1	5.4	Y
SI	L	6		0	10	5	1	4.9	y
SI	L	20		0	2.5	5	2	4.8	N
SI	L	6		0	2.5	5	1	5	Y
SI	L	20	7.5 6/8	1	10	6	2	4.8	Y
SI	L	6		0	10	5	1	5.3	Y
SI	L	20	5 5/8	1	2.5	5	2	4.8	Y
SI	L	6		0	10	4	1	4.6	Y
SI	L	6		0	2.5	4	2	4.9	Y
SI	L	20		0	10	5	1	4.6	Y
SI	L	6		0	10	5	1	4.9	Y
SI	L	12		0	10	5	1	5.4	Y
SI	L	20		0	2.5	4	1	4.8	Y

SI	L	8		0	10	5	1	5.3	Y
SI	L	15		0	10	4	1	4.5	Y
SI	L	20		0	10	4	1	5.3	Y
SI	M	3	5 5/8	1	10	5	1	4.7	Y
SI	M	10	5.625	1	10	5	1	4.9	Y
SI	M	20	5.77	1	10	6	1	4.6	Y
SI	M	3	7.5 8/8	1	10	5	1	5.2	Y
SI	M	10	7.5 5/8	1	10	6	1	4.6	Y
SI	M	20	5 5/8	1	10	6	1	4.7	Y
SI	M	3		0	2.5	5	2	5.1	Y
SI	M	10	5 6/8	1	10	5	1	4.9	Y
SI	M	20	5 6/8	1	10	6	1	4.3	Y
SI	M	3	5 6/8	1	10	5	2	5	Y
SI	M	10	7.5 5/8	1	10	6	1	5	Y
SI	M	20	5 5/8	1	10	5	1	4.9	Y
AB	U	2		0	10	3	1	6	N
AB	U	8	7.5 6/8	1	10	5	2	5.7	N
AB	U	20	5 5/8	1	2.5	5	2	5.6	N
AB	U	2		0	10	3	1	6	N
AB	U	8	5 5/8	1	2.5	5	2	5.8	N
AB	U	20	5 5/8	1	2.5	5	2	5.5	N
AB	U	2		0	10	4	2	5.9	N
AB	U	8	7.5 6/8	1	2.5	5	2	5.8	N
AB	U	20		0	2.5	5	2	5.9	N
AB	U	2		0	10	3	1	5.6	N
AB	U	8	5 5/8	1	2.5	5	2	5.8	N
AB	U	20	5 5/8	1	2.5	5	2	5.3	N
AB	U	2		0	10	3	2	6.6	N
AB	U	5		0	10	6	3	5.9	N
AB	U	20	7.5 6/8	1	10	6	3	5.6	N
AB	U	2		0	10	3	2	6.5	N
AB	U	5		0	10	6	3	6.6	N
AB	U	20	7.5 6/8	1	10	6	3	5.3	N
AB	U	2		0	10	3	2	6.2	N
AB	U	5		0	10	6	3	6.8	N
AB	U	20	7.5 6/8	1	10	6	3	6.5	N
AB	U	2		0	10	3	2	6.4	N
AB	U	5		0	10	6	3	5.4	N
AB	U	20	7.5 6/8	1	10	6	3	5.7	N

AB	U	1		0	10	3	2	6.4	N
AB	U	4		0	10	5	3	6.2	N
AB	U	20	7.5 6/8	1	10	6	3	5.8	N
AB	U	2		0	10	3	2	6.1	N
AB	U	5		0	10	6	3	6.2	N
AB	U	20	7.5 6/8	1	10	6	3	6	N
AB	U	2		0	10	3	2	6	N
AB	U	5		0	10	6	3	5.8	N
AB	U	20		0	10	6	3	5.9	N
AB	U	2		0	10	3	2	6	N
AB	U	5		0	10	5	3	6	N
AB	U	20	7.5 6/8	1	10	6	3	6.5	N
AB	L	.5		0	7.5	3	2	4.6	N
AB	L	4	5 5/8	1	10	5	1	5.1	N
AB	L	20	5 5/8	1	10	5	1	5.4	N
AB	L	.5		0	7.5	3	2	4.7	N
AB	L	4	5 5/8	1	10	5	1	5	N
AB	L	20	5 5/8	1	10	5	1	5.4	N
AB	L	.5		0	7.5	3	2	4.5	N
AB	L	4	5 5/8	1	10	5	1	5.1	N
AB	L	20	5 5/8	1	10	5	1	5.3	N
AB	L	.5		0	7.5	3	2	4.7	N
AB	L	4	5 5/8	1	10	5	1	5	N
AB	L	20	5 5/8	1	10	5	1	5.1	N
AB	L	1	5 5/8	1	10	4	1	3.9	N
AB	L	15	5 4/6	1	10	5	1	4.5	N
AB	L	20	5 4/6	1	10	4	2	4.2	Y
AB	L	1		0	10	3	2	3.8	N
AB	L	15	5 5/6	1	10	5	2	4.8	N
AB	L	20	5 4/6	1	10	4	2	4.5	Y
AB	L	1		0	10	3	2	4.1	N
AB	L	15	5 5/8	1	10	6	1	4.6	N
AB	L	20	5 4/6	1	10	4	1	4.3	Y
AB	L	1	5 5/8	1	10	4	2	4.2	N
AB	L	15	5 5/8	1	7.5	5	1	4.7	N
AB	L	20	5 5/8	1	10	4	2	4.4	Y
AB	L	2		0	10	5	1	4.2	N
AB	L	8	5 4/6	1	10	4	2	5.6	N
AB	L	20	5 4/6	1	10	4	2	5.1	N

AB	L	2		0	10	5	1	4.4	N
AB	L	20	7.5 5/8	1	10	5	1	5.2	Y
AB	L	2		0	10	5	1	4.5	N
AB	L	8	7.5 5/8	1	10	5	1	5	N
AB	L	20	7.5 5/8	1	10	5	1	5.3	N
AB	L	2		0	10	5	1	4.4	N
AB	L	8	7.5 5/8	1	10	5	1	4.9	N
AB	L	20	7.5 5/8	1	10	5	1	4.8	Y
AB	M	4		0	10	4	2	6.1	N
AB	M	15	5 4/6	1	10	6	2	5.3	N
AB	M	20	10 5/8	1	10	6	2	5.5	N
AB	M	3		0	10	4	2	5.8	N
AB	M	15	7.5 5/8	1	10	5	1	5.6	N
AB	M	20	7.5 5/8	1	10	5	1	5.7	N
AB	M	3		0	10	4	2	5.5	N
AB	M	15	5 4/6	1	10	6	2	5.4	N
AB	M	20	10 5/8	1	10	6	2	5.6	N
AB	M	2		0	10	4	2	5.8	N
AB	M	12	10 5/8	1	10	5	3	5.5	N
AB	M	20	7.5 5/8	1	10	6	2	6	N
AB	M	3		0	10	5	2	5.5	N
AB	M	6	7.5 5/8	1	10	6	2	5.5	N
AB	M	20	7.5 5/8	1	10	6	2	5.5	N
AB	M	3		0	10	5	2	5.6	N
AB	M	6		0	10	6	2	5.4	N
AB	M	20	7.5 5/8	1	10	6	2	5.4	N
AB	M	3		0	10	5	2	5.4	N
AB	M	6		0	10	6	2	5.2	N
AB	M	20	7.5 5/8	1	10	6	2	5.3	N
AB	M	3		0	10	6	2	5.3	N
AB	M	6	7.5 5/8	1	10	6	2	5.4	N
AB	M	20	7.5 5/8	1	10	6	2	5.6	N
AB	M	6		0	10	4	2	5.9	N
AB	M	6		0	10	4	2	6.2	N
AB	M	20	7.5 6/8	1	2.5	7	2	5.6	N
AB	M	1		0	7.5	3	1	6	N
AB	M	5	5 5/8	1	10	4	2	5.8	N
AB	M	20	7.5 6/8	1	2.5	7	2	6.3	N
AB	M	2		0	7.5	3	1	6.2	N
AB	M	5	7.5 6/8	1	10	5	2	5.8	N

AB	M	20	7.5 6/8	1	2.5	7	2	5.6	N
AB	M	2		0	7.5	3	1	6.4	N
AB	M	5		0	10	4	2	6.2	N
AB	M	20	7.5 6/8	1	2.5	7	2	5.3	N

CONTACT INFORMATION

Name:	Deseri Dawn Nally
Professional Address:	c/o Dr. Georgianne Moore Department of Ecosystem Science Texas A&M University College Station, TX 77843
Email Address:	D4nall32@tamu.edu
Education:	B.A., Ecological Restoration, Texas A&M University, May 2012 Undergraduate Research Scholar